Electronic Services - Los Angeles
M10493X

OPERATING & SERVICING MANUAL

F. W. BELL INC.

MODEL 1390

MAGNETIC REACTION AMPLIFIER

MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.
SANTA MONICA/CALIFORNIA

DOUGLAS

MODEL 1390

MAGNETIC REACTION ANALYZER

OPERATING AND SERVICING

MANUAL

(TEMPORARY)

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SECTION I

SPECIFICATIONS MODEL 1390
MAGNETIC REACTION ANALYZER
WHEN USED WITH THE MODEL 1090 MRA

FREQUENCY RANGE:	20 c/s to 20 k c/s
FREQUENCY ACCURACY OF PLUG IN FILTER:	±3% of frequency marked on plug in filter
HALL CURRENT:	200 mA dc nominal
HALL CURRENT STABILITY:	±0.25% after warmup
ELECTRICAL RESPONSE LINEARITY:	±0.25% of full scale from 10% to 100% of full scale
METER LINEARITY:	±1% of full scale
METER RESOLUTION:	Smallest scale division is 1% of full scale
PROBE MAGNETIZING FORCE:	20 Oe rms ac at center of probe surface normally (may vary with special probe configurations)
PROBE COIL CURRENT:	0.5 amp rms ac nominally 20 c/s to 20 k c/s
HALL DEVICE SENSITIVITY TEMPERATURE COEFFICIENT:	Less than -0.08% per ^{o}C at 25^{o} C
POWER REQUIREMENTS:	Operates from power supplies within the Model 1090
SIZE:	Bench model 16 3/4" wide 6" high 12 1/4" deep Rack model 19" wide 5 1/4" high 11 1/2" deep behind panel 13" deep overall
WEIGHT:	10 lbs. net 19 lbs. shipping

SECTION II

INTRODUCTION

II-1 GENERAL

The Differential Magnetic Reaction Analyzer* is a sensitive eddy-current instrument for nondestructive materials testing. This instrument permits noncontacting measurement of the local variation in magnetic and electrical properties of metallic materials over a wide thickness range, typically from a fraction of a mil to 1/2" thicknesses. It is capable of operation at frequencies varying from 20 c/s to 20 kc to provide optimum operation conditions for each combination of material properties and geometries. It uses a balanced differential pick-up that provides high sensitivity to sharply defined discontinuities in the material, and because of the differential operation is inherently less sensitive to gradual changes in material properties and environmental conditions. The two features which make this instrument both unique and unusually versatile are the use of a constant amplitude magnetizing field and sensitive field detection devices with flux response independent of frequency. The use of a current-regulated ac supply for magnetizing coil current provides constant magnetizing force at all frequencies. The use of Hall devices to detect the magnetic field facilitates the use of phase as well as amplitude information over the full frequency range and extends the usable frequencies to very low values without loss of sensitivity. Deeper penetration as well as measurement of very high conductivity materials is thus possible.

The Differential MRA lends itself to operation in an industrial environment because of the high attenuation filters that serve to suppress electrical noise such as transients and stray frequency pick-up. Changes of only a few per cent of full scale deflection on the absolute reading MRA 1090 can produce signals of full scale output on the MRA 1390.

II-2 DIFFERENTIAL MAGNETIC REACTION ANALYZER SYSTEM

The Differential Magnetic Reaction Analyzer instrumentation system includes the following basic elements:

A. A variable-frequency, highly-stabilized, constant-current oscillator to provide magnetizing current.

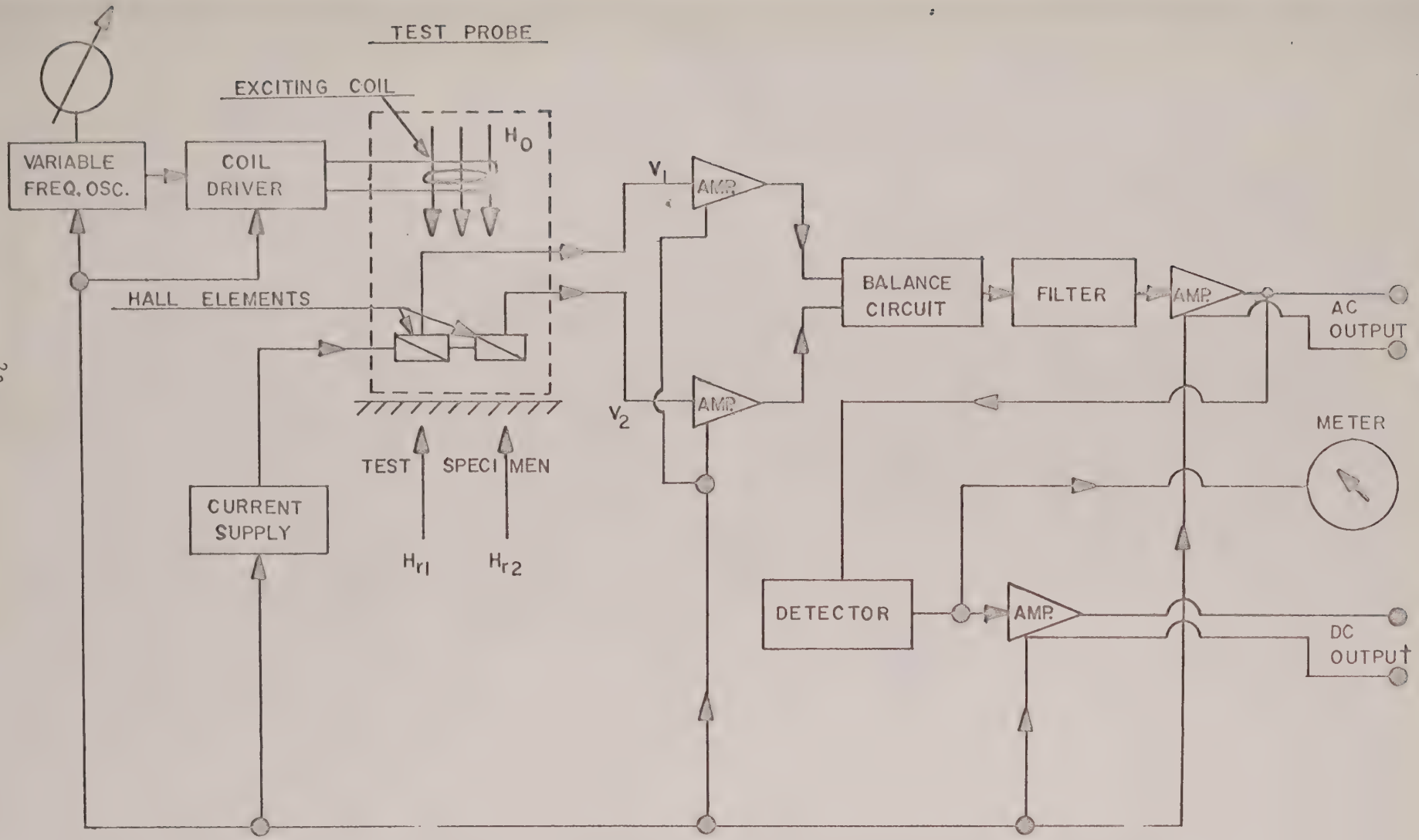
B. Test probes of various geometries, each containing a simple magnetizing coil excited at constant current, and miniaturized Hall devices to pick up the magnetic reaction of the test material to the magnetizing field.

C. Stable amplifiers, sensitivity and phase balance controls, narrowband filter plug-in units, and discrimination circuits permit the display of the difference output of two Hall devices such that very small reaction field disturbances can be expanded many times.

Both ac and dc output terminals are provided to permit the drive of servo correction systems and recorder systems for instantaneous control and marking as well as permanent record charts.

Figure 1 shows the basic connections between these system elements.

*Patent Pending



SIMPLIFIED BLOCK DIAGRAM - DIFFERENTIAL MAGNETIC REACTION ANALYZER

H_0 — EXCITING FIELD

H_r — REACTION FIELD

F.W. BELL, INC. COLUMBUS, OHIO

FIG. 1

2a

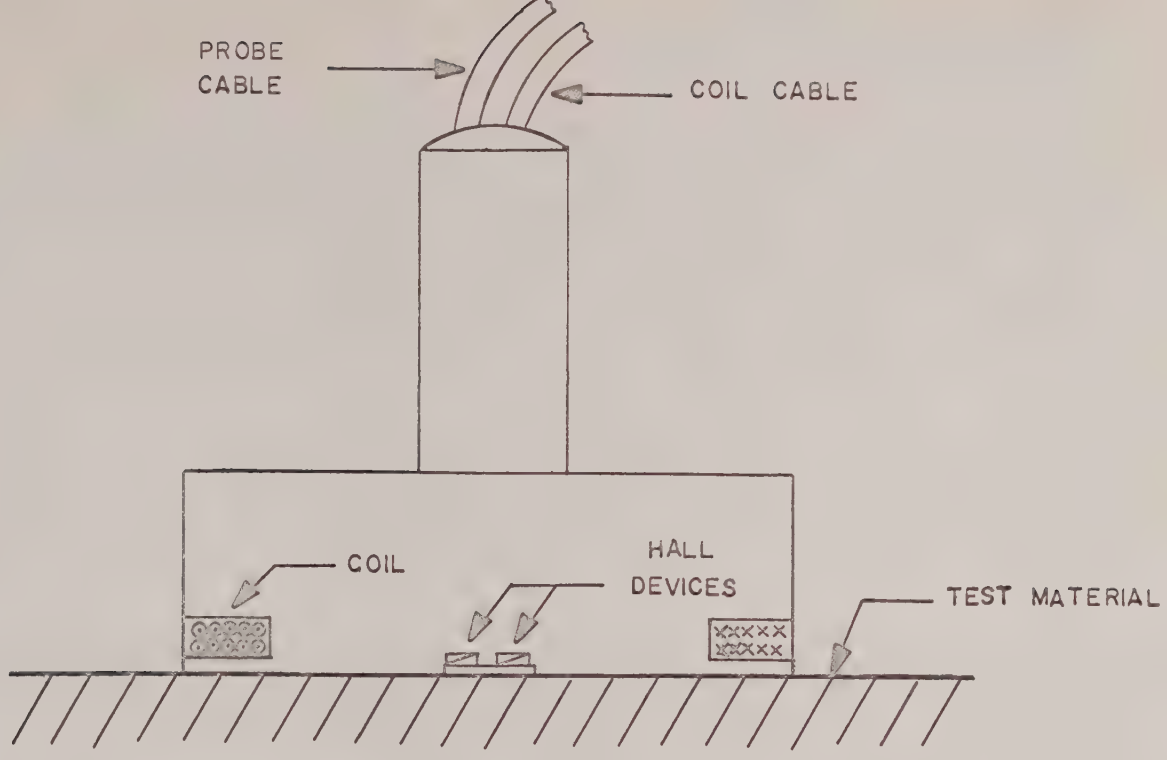


FIG. 2a. STANDARD DIFFERENTIAL TEST PROBE (2 DEVICES)

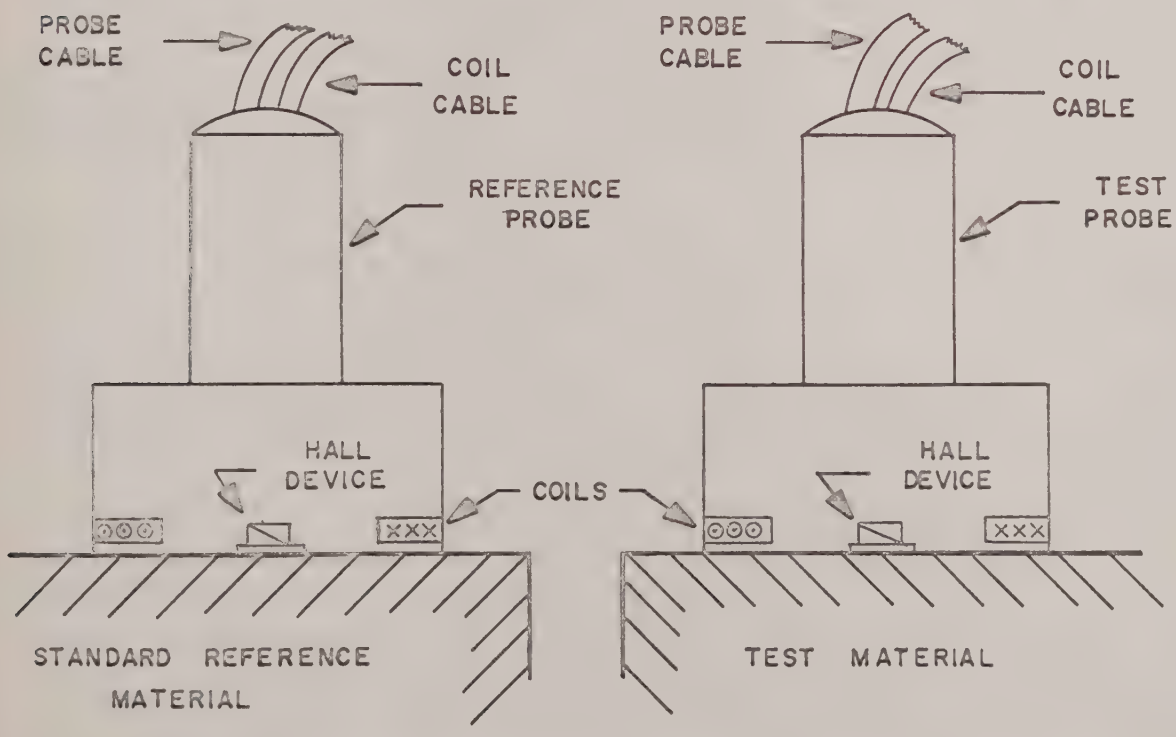


FIG. 2b. TWO STANDARD SINGLE DEVICE PROBES CONNECTED DIFFERENTIALLY.

FIG. 2. TYPICAL DIFFERENTIAL TEST PROBE ARRANGEMENTS.

II-3 TYPICAL DIFFERENTIAL PROBE ARRANGEMENTS

Figure 2 shows two typical probe arrangements. The standard differential probe is shown in Figure 2a and includes a magnetizing coil of circular shape. It also contains two Hall device pick-up elements, thin semiconductor wafers located on the axis of the magnetizing coil, and close to the face of the probe. These Hall elements sense both the magnetizing field of the coil, and the magnetic reaction field of the test material. nearly 100% coupling efficiency when the probe face is in contact with or close to the surface of the test material.

Two single device probes can also be used for testing with the Differential MRA as shown in Figure 2b. This arrangement is particularly valuable for production testing of materials where the test piece geometry is irregular. These geometry affects become normalized when both the reference and test probes are balanced on the same geometries.

Other probe assemblies could contain one or more magnetizing coils designed to shape and limit the magnetizing field, to null the magnetizing field at the Hall elements, to provide polarized eddy currents, or to fit the contours of special test parts. In addition, more Hall devices may be disposed variously to detect local variations in reaction fields, or to limit detection to desired components of the reaction fields. Since the Hall devices are sensitive to the direction of the magnetic field to which they are exposed, they can be placed to detect the magnetic field component normal to the surface of the test material, tangential to the surface of the test material, or in arrays to detect the spatial vector components of reaction fields. In the probes sketched in Figure 2, an axial Hall device is located at the probe faces in a plane parallel to the coil faces and the test material surfaces to measure the normal component of field along the coil axis and perpendicular to the surface of the test material.

SECTION III

THEORY OF THE DIFFERENTIAL ANALYZER

III-1 GENERAL

Operation of the two Hall devices located within a single excitation coil (Figure 2a) does not differ in theory from the operation of two Hall devices where each is located within a separate excitation coil, (Figure 2b), both coils being identical and driven in series with the same excitation current. Therefore, both of these situations will actually be covered though the discussion will refer to two Hall devices within the same excitation field, $\overline{H}_o$.

III-2 MAGNETIC REACTIONS ON CONDUCTIVE MATERIALS

With the probe located in a media that is essentially nonconductive and nonmagnetic (such as air), the two Hall devices of Figure 1 are both in a downware field, $\overline{H}_o$, produced by the excitation coil that surrounds them.

When the probe is placed in close proximity to a conductive test specimen, the $\overline{H}_o$ field penetrates into the material and generates eddy currents within the material. The eddy currents, a function of the material properties, thickness and geometry, produce a reaction field, $\overline{H}_r$, which vectorially adds to $\overline{H}_o$ producing a net field $\overline{H}_n$ at the Hall device.

$$\overline{H}_o + \overline{H}_r = \overline{H}_n$$

Since the reaction field $\bar{H}_r$ is primarily in a direction that opposes $\bar{H}_o$, the net field is reduced from its value in air except under circumstances where extreme field distortion occurs, such as at the edge of a material.

In a continuous (nondefective) area of the material being examined, $\bar{H}_{r1}$ and $\bar{H}_{r2}$ are essentially equal. Since $\bar{H}_o$ is constant throughout this area, then $\bar{H}_{n1}$ and $\bar{H}_{n2}$ are also equal. The Hall devices are mounted in close proximity to the test specimen and when fed from the dc constant current supply produce voltages which are proportional to the net fields, $\bar{H}_{n1}$ and $\bar{H}_{n2}$. A difference voltage proportional to V1-V2 is then nulled, amplified, filtered, detected and fed to the panel meter and output jacks for direct reading of the difference of the net fields $\bar{H}_{n1}$ and $\bar{H}_{n2}$.

When a local discontinuity disturbs the normal eddy current flow under one of the Hall devices, the reaction field, $\bar{H}_r$, at that point is changed. The equilibrium of the difference voltage from the two net fields, $\bar{H}_{n1}$ and $\bar{H}_{n2}$, is destroyed and takes on a voltage value proportional to the change of the reaction field at the points of disturbance. This voltage is available in the form of an ac sinusoidal signal, a dc signal level or a meter reading. Thus any local property change and/or geometrical change which causes an alteration of the eddy current reaction field, amplitude or phase, will be detected by the Differential Magnetic Reaction Analyzer to the exclusion of gradual variations in these properties.

III-3 MAGNETIC REACTION ON MAGNETIC MATERIALS

In the case of magnetic materials, the signal analysis is the same except all vectors are increased in magnitude by a measure of the materials permeability, μ eff. In air, the individual Hall device would respond to a field

$$\bar{B}_o = \mu \text{ eff } \bar{H}_o$$

The output voltages V1 and V2 would be increased proportionately, so that a noted increase in sensitivity will be experienced with comparable surface conditions. A reduction in penetration depth will also be noted with any ferromagnetic material which provides a low reluctance path for the excitation field and essentially shunts a larger percentage of this field along its surface.

SECTION IV

APPLICATION OF THE DIFFERENTIAL ANALYER

IV-1 GENERAL

Tests have been conducted on samples in a number of areas and a few of these areas will be described. They are intended only as an introduction to the possible applications of the Differential MRA.

IV-2 COMPARISON TESTING

Using two individual test probes as shown in Figure 2b, materials having relatively small differences in physical properties can be easily separated even at production rates of speed. Minor variations in conductivity, permeability and geometry can be expanded where acceptable test standards are used to effect a balance.

This is an especially valuable technique when measurements are required on a piece having a complex geometry that serves to distort the natural paths of eddy current flow. Comparison of properties become feasible under these circumstances only when the effects of the complex geometry have been normalized. If both the reference and test probes are located identically on pieces of like geometry, property comparison can be made.

To establish the acceptable range for the property of interest, standards that represent the acceptable limit and some intermediate stages of it should be used. With these it is possible to determine the out-of-balance signals produced when the standards of known variation are placed under the test and compared to the acceptable standard that remains under the reference probe. This procedure will provide the needed information to produce a calibration curve from which the selection of the desired alarm level can be made for rejection of a sub-standard part. For suggested alarm level units to be used in conjunction with the Differential MRA, see page 9.

IV-3 DISCONTINUITY DETECTION

Either probe arrangement has its advantages and may be useful to perform discontinuity analysis on a test part. The two probe method would find application where complex geometries were involved. Using a fixture that would allow the surface of a test piece to be scanned simultaneously with that of the reference piece and at correspondingly identical locations on both pieces, discontinuities could be indicated irrespective of the irregularity of the geometry of the part.

In many applications of this sort, a dual Hall device probe will provide several advantages. Long term changes that are generally not detrimental to the integrity or life of the part (such as thickness or general contour changes) will affect both Hall devices alike and hence will not produce an output. Effects of ambient temperature variations are also minimized where the two devices are located in close proximity.

Balance is achieved in this case, with the probe in the normal inspection position on a known-nondefective test standard. Ideally, the test standards used should be identical in all respects to the pieces to be inspected.

To establish alarm levels for repair and/or reject catagories of parts, standard defects are frequently machined to ensure reproducibility. The dimensions, orientation, and location of these standards should be chosen to best represent the natural defects of interest. The correlation of signals produced by natural and fabricated discontinuities is an essential part of the success of any such test application. For suggested alarm level units to be used in conjunction with the Differential MRA, see page 9.

IV-4 WELD OR EDGE TRACKING

The edge of a conductive material restricts the flow of eddy current as an MRA test probe approaches that edge. A similar distortion of the eddy current flow is produced upon approaching an area that differs metallurgically from the parent material, such as is often represented at a weld. This distortion of the paths of eddy current flow are in many cases quite dynamic and may be used to advantage with an appropriate Hall sensor arrangement.

The two Hall devices of a differential probe are individually affected by an edge. Upon approaching an edge, the signal of each device is affected alike in amplitude but oppositely in phase because of the inherent characteristics of a differentially connected pair of Hall devices. When a differential probe is positioned over a weld (or edge) so that the Hall elements straddle the weld, an interesting effect on the MRA output is created. This effect is demonstrated in Figure 3. The phase and amplitude information of these outputs is quite suitable for weld guidance of the electrodes or torch, or for accurate positioning of an inspection head either over or a fixed distance away from a weld. For a suggested servo package that will work directly from the Differential MRA output, see page 10.

SECTION V

OPERATION OF THE DIFFERENTIAL MAGNETIC REACTION ANALYZER

V-1 PANEL CONTROLS

Refer to the MRA 1090 manual for description of controls etc. on the 1090 instrument.

Mode Switch:

Selects normal 1090 operation or differential 1390 operation.

Balance Controls:

A resistive balance control and coarse and fine capacity balance controls are used to establish an accurate balance with the probe or probes used in the differential test arrangements.

Gain Control:

This control adjusts the amplifier gains and essentially selects the level of pick-up sensitivity.

V-2 EXTERNAL CONNECTIONS

Probe Socket:

The six-pin probe socket on the panel accepts the mating cable connector of the differential test probe. In the case where two single Hall device probes are used differentially, their multipin connectors are to be plugged into the junction box unit MRP-JB. The junction box multi-lead cable connector is then plugged into the six-pin probe socket of the 1390 panel.

Interconnecting Cable Socket:

Located on the rear of the instrument is the socket for the interconnecting cable between the 1390 and 1090. Make sure the jumper cable is securely connected and the clamp ring tightened to prevent disconnection.

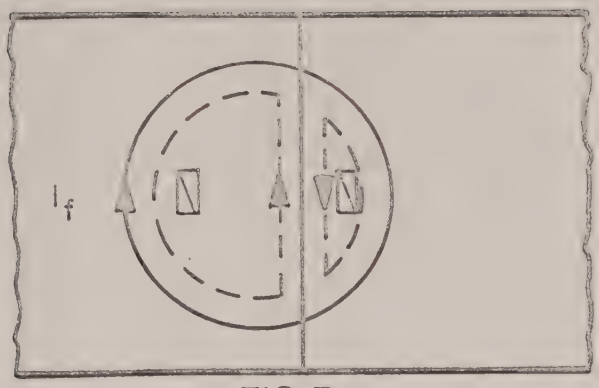


FIG. 3a

PROBE POSITIONED JUST TO LEFT OF WELD CENTER.

OUTPUT

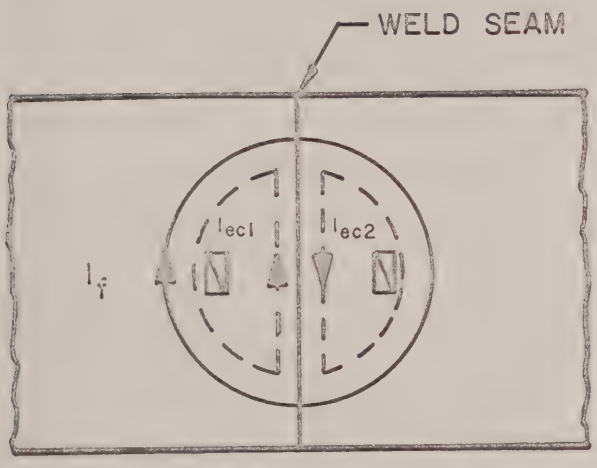


FIG. 3b

PROBE CENTERED OVER THE WELD

OUTPUT

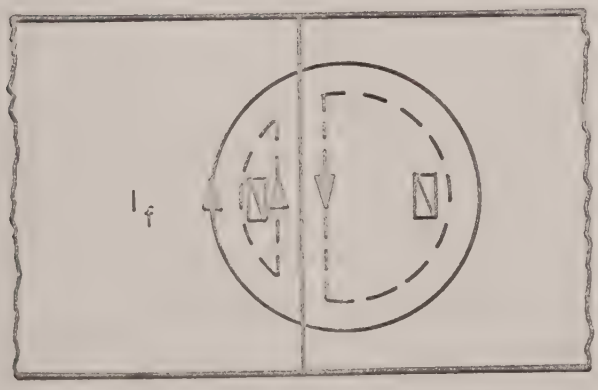


FIG. 3c

PROBE POSITIONED JUST TO RIGHT OF WELD CENTER

OUTPUT

FIG. 3

DIFFERENTIAL MRA OUTPUT SIGNALS PRODUCED FOR VARIOUS PROBE POSITIONS OVER A WELD.

Outputs:

Both ac and dc outputs are provided. The ac output amplitude is proportional to the difference signal of the two Hall devices and its phase, dependent on test material properties, is related to that of the signal at the frequency jacks on the panel. The dc output jacks are provided for connecting the instrument to external recording devices. The voltage available at these jacks is 2 V dc for a full-scale meter reading, with less than 10% ripple at 20 Hz. The ac output jacks produce approximately 2 V rms for full-scale meter reading at a source impedance of less than 1 Ω. Loads drawing a maximum of 10 mA (200 Ω) may be used. A short circuit or loads of less than 200 Ω will cause no damage but current limiting will occur and may cause erroneous output voltages at the terminals. The dc output jacks produce approximately 2 V dc for full-scale meter reading at a source impedance of less than 10 Ω. Loads drawing a maximum of 1.5 mA may be used. Excessive loading of these terminals will cause nonlinearities and erroneous meter readings but will not damage the instrument. The dc output jacks on the MRA 1090 may be used to obtain lower impedance and higher output current if desired.

V-3 INITIAL OPERATING ADJUSTMENTS

Probe Description:

Although ruggedly constructed, reasonable care should be used in handling the probe to prevent severe shock from being applied to the probe end. The Hall elements are fragile and can be fractured. It is protected by being completely and solidly encapsulated in epoxy on the probe end. The maximum working temperature of the Hall element is +100° C, but it has a sensitivity variation with temperature amounting to about -0.08% per deg C.

Mode Switch:

For differential operation set the mode switch to differential. This connects the 1090 and 1390 and sets the instruments to operate together. With the mode switch in the normal position, the model 1090 operates in its normal fashion independent of the 1390.

MRA 1090 Control Settings:

Set the controls on the model 1090 as follows:

I_f CAL set to obtain full scale meter reading when the button is pushed.

CAL control to minimum (CCW).

ZERO controls at any setting.

FUNCTION SWITCH to CAL.

FREQUENCY controls to match filter frequency as described below.

INTERPOLATE control to any setting.

Applying Power:

Before turning the instrument on, make certain that the available power matches the voltage and frequency rating on the instrument, see 1090 manual. Connect the probe cable connector to the frontpanel receptacle, making certain that plug is securely in place. Connect the BNC coil connector to the coil receptical on the 1090 panel. The ON-OFF power switch is located in the upper left corner of the 1090 front panel; the power ON indicator lamp is located just to the right of the switch.

Meter Zero:

The meter mechanical zero can also be checked prior to turning the instrument on. If necessary, set the pointer to read exactly zero, when viewed directly from the front and when aligning the reflected image of the pointer directly under the pointer itself to avoid parallax. Use the small screw on the lower portion of the meter case.

Stabilization:

Allow 2 to 5 minutes for the instrument to stabilize before balancing. Full stability is reached after 15 to 20 minutes. Balance should be checked periodically until the instrument characteristics have become established for a particular application.

Frequency Selection:

The MRA filter unit located in the front panel of the 1390 is a plug-in section. It contains filters that pass the operating frequency (which is indicated by the unit number, MRF-400 for 400 c/s, etc.) and attenuate all others. These units are available in 22 frequencies, as follows: 30, 50, 60, 90, 100, 120, 150, 200, 240, 300, 400, 500, 750, 800, 1000, 1500, 2000, 3000, 4000, 5000, 10,000, and 20,000 c/s. Attenuation is approximately 4 db at $\pm$3% of the pass frequency and 70 db per octave.

The frequency of the oscillator must be set to match the filter unit. Adjust the frequency controls on the MRA 1090 to the indicated frequency of the filter unit, with the MRA 1390 gain at minimum (full CCW). Set the resistive balance control to maximum CW and bring the gain up until about half of full scale meter reading is obtained. Tune the vernier frequency control to maximize the meter reading using the gain control to keep the meter on scale. After the frequency is set, the balance controls may be adjusted to obtain the desired balance as described below.

Balance Procedure:

Balance over a test piece is accomplished using the resistive and capacity balance controls. The resistive control is a ten-turn potentiometer providing a means of accurately balancing over a broad sensitivity range. Two separate controls are used for a coarse and fine adjustment of the capacity balance.

In setting up for a balance, the probe or probes should be positioned and referenced to a surface or surfaces that represent the actual conditions for test in order to achieve the best accuracy. To initiate a balance, the gain control

should be adjusted for about half scale meter deflection. Alternate adjustment of the resistive and capacity balance controls can then be made until the meter is zeroed. Again, the gain can be increased and balance controls adjusted for the best meter null. This procedure may be followed until the gain is increased to its full clockwise position (full gain). This represents the point of greatest sensitivity for the particular arrangement of probe and test piece.

If movement of the test piece under the probe is too critical, the gain will have to be reduced to suit the conditions. Mechanical handling is of extreme importance at this point, and the employment of a well designed jig to hold or reference to the test piece, or of a shaped or contoured housing for the test probe, will frequently allow operation at a substantial increase in sensitivity level.

As experience is gained, these operations will become quite simple. The advantages that accompany complete familiarity with both the instrument and the area of eddy current testing are numerous. Novel probe configurations and probe positions are often the key to the solution of material evaluation problems with eddy current testing techniques.

SECTION VI

PRACTICAL USE OF THE MAGNETIC REACTION ANALYZER

VI-1 GENERAL

The combination of the Magnetic Reaction Analyzer models 1090 and 1390 provide a most complete eddy current evaluation system. Basic evaluation tests can be performed with absolute readout of magnetic vector units with the model 1090 over a continuous frequency range from 20 Hz to 100,000 Hz. From these tests, the frequency of primary interest can generally be selected that will emphasize the variable of interest and minimize the effects of known variables that are of no consequence. A series of prepared test samples are of particular value in this type of testing. Upon selection of the most desirable frequency, the differential reading model 1390 can be used to expand the sensitivity of the read-out many times at the optimized frequency. When such a calibration has been determined and the test is ready to be adapted to a production system, units available from F. W. Bell, Inc., that may be of interest are described below.

VI-2 ADJUSTABLE ALARM LEVEL UNITS

Two units are commercially available that offer two adjustable limits (HU-7004) and five adjustable limits (HU-7005), respectively. They are designed to accept the MRA dc output and sort on the basis of voltage levels. Both an indicator output and a relay contact output is available from each limit level adjustment. Upon reaching the pre-set level of a limit, its indicator lights and the relay control change state. Marking devices and kick-out mechanisms can be operated from these contacts.

VI-3 SERVO PACKAGE

A servo package is commercially available for weld or edge-following applications. It will provide a mechanical shaft rotation proportional to the amount of off-set and in the direction of off-set of the differential probe from the weld center. This will prove useful in weld guidance applications as well as inspection head referencing on, or a fixed distance from, the weld. It is designed to operate directly from the signals available at the output jacks of the differential MRA.

VI-4 SYSTEM FOR PRODUCTION LINE DIFFERENTIAL EDDY CURRENT TESTING

The MRA model 1290 is a self-contained differential instrument for high sensitivity eddy current inspection and control. Its simplified controls lend it to use in an industrial environment by non-engineering personnel. The model 1290 provides the full capabilities of the 1390 but displays only the essential operating features.

SECTION VII

CIRCUIT OPERATION THEORY

VII-1 GENERAL

This section describes the overall MRA 1090-1390 combination circuit operation. Details concerning the change over from 1090 to 1390 operation are not shown for clarity. Check the complete schematics of both instruments for these details. Additional descriptions covering the more detailed operating theory of the individual module boards (amplifier oscillator, etc.) are contained in the following sections.

The MRA system may be divided into five separate circuit groups:

1. Oscillator - Current Amplifier
2. DC Current Supply
3. Amplifier - Detector - Output Amplifier
4. Power Supply
5. Plug-in Filter

Figure 4 shows the functional block diagram of the MRA system. All unnecessary details have been omitted to avoid confusion. The description is general in nature for the purpose of giving a simplified insight into the circuit operation. Check the complete schematic (figure 5) for all detailed circuit operation and servicing information.

VII-2 OSCILLATOR - CURRENT AMPLIFIER

The ac current to the probe excitation coil for production of eddy currents in the material under test is supplied from an oscillator power amplifier combination (contained within the 1090).

The oscillator (Model 1150) is a Wein bridge type with a highly stable amplitude regulating circuit. The modular circuit board contains the amplifier and amplitude-regulating circuits. The actual Wein bridge consists of capacitors C1 thru C17, and resistors R13 thru R15.

The oscillator output is about 2.1 V rms, and is attenuated to 0.5 V rms, through the I_f CAL control (R44). The I_f CAL control adjusts the input level to the power amplifier to give 0.5 amp output.

The ac current amplifier (model 1157) is a high-gain amplifier with current feedback from the output. Hence, the output current is directly proportional to the input voltage; and load impedance changes caused by the coil inductance at various frequencies will not change the output current. The voltage drop accross the sensing resistor R_I provides the frequency output signal. To prevent accidental shorting of R_I and causing the current to rise, R39 is put in series with the frequency jack.

VII-3 DC CURRENT

The nominal 200 mA Hall control current is supplied from the dc current regulated power supply (model 1156). Since neither of the power supply terminals may be grounded the current supply is operated from an isolated power source from the power amplifier. The control current is adjusted to the 200 mA by means of the adjustment on the circuit board and the CAL control R40.

VII-4 AMPLIFIER - DETECTOR - OUTPUT AMPLIFIER

The two Hall devices feed into the inputs of the dual preamplifiers giving a gain of about 2000. The preamplifier outputs are out of phase and are effectively subtracted from one another at the zeroing controls. The difference signal is fed to the amplifier through the first section of the gain control. The difference signal is amplified and filtered through the three-channel amplifier to give very high differential sensitivity.

The three-channel amplifier output is then applied to the unity gain output amplifier to provide the ac output and to the detector to provide the dc output. The meter is connected to the dc output to indicate the difference signal.

VII-5 POWER SUPPLY

With the exception of the dc current regulator, which operates from its own separate unregulated supply, all of the remaining circuits operate from the $\pm$15 V regulated supply (model 1159), contained within the 1090. The ac current amplifier is decoupled by 7.5 Ω resistors and 50 μF capacitors to prevent high-frequency signals from being impressed on the power-supply output. Also, the amplifier and detector are isolated from the + and -15 V busses by a pair of 12 V zeners to again prevent any power supply noise or transients from affecting these sensitive circuits.

VII-6 PLUG-IN FILTER

The plug-in filter contains two narrow band filters which are connected between three sections of the three-channel amplifier. Also the filter contains the Wein bridge circuit for the oscillator and is adjusted to match the filter frequency. The Wien bridge circuit is used only in the MRA 1290 and is unused in the MRA 1390.

SECTION VIII

ALIGNMENT PROCEDURE

VIII-1 GENERAL

The following alignment information is given for the purpose of maintaining the model 1390. Adjustment should be carried out in the field only where adequate test equipment and qualified personnel are available. Align the model 1090 according to the description in the 1090 manual before attempting to adjust the 1390. The following description is for the additional alignment required for the model 1390 only.

VIII-2 TEST EQUIPMENT

A. Good wide-band VTVM such as Hewlett Packard Model 400 H or 400 D.

B. An accurate dc VTVM such as Hewlett Packard Model 412 A.

C. An adjustable line voltage source accurately metered.

VIII-3 PRELIMINARY

A. Connect the MRA 1090 to 117 V line voltage and turn on.

B. With the probe and coil connected, set the 1090 controls as described on page 7 and the 1390 controls as follows:

1. Balance controls for good zero at maximum gain (probe remote from test pieces);
2. Gain at minimum (full CCW).
3. Mode to differential.

C. Allow instrument to warm up for one hour with cover in place.

D. Circuit board line up in order proceeding from the probe socket end of the instrument.

1. Model 1155 DC Amplifier
2. Model 1154 Detector
3. Model 1153 Three-channel Amplifier
4. Model 1151 Two-channel Preamplifier

VIII-4 DC AMPLIFIER ZERO

Connect the dc VTVM to the ac output jacks and with the gain turned to minimum (CCW) adjust the trimmer on the model 1155 board for zero reading on the VTVM's 0.1 V full scale range.

VIII-5 DETECTOR ADJUSTMENTS

With the gain at minimum, connect the dc VTVM from ground to the junction of R13, R14, R20, C5, and Q3 emitter on the detector board model 1154. Use the board extender. Note the voltage and then connect the dc VTVM from ground to the detector output. Adjust R4 until the dc meter reads the same.

Connect the ac VTVM to the ac output jacks and the dc VTVM to the dc output jacks. Set the gain control to about half setting and adjust the resistive balance control to obtain 2 V dc on the dc VTVM. Note the reading on the ac VTVM 3 V range. Reduce the gain until the ac VTVM reads the same on the 0.3 V range. The dc VTVM should read 0.2 V $\pm$2%. If it does not read 0.2 V, adjust R1 on the detector board to obtain this 0.2 V reading.

SECTION IX

TROUBLE SHOOTING

The following suggestions are recommended when difficulty is encountered in the operation of the instrument.

Check the inputs and outputs of the module boards to localize the difficulty. DC and ac voltages or currents at inputs and outputs of the modules are given on the block diagram. They are approximate and will vary depending on the operating mode but should give an indication of whether or not the module is operating.

Check the individual module schematics and circuit descriptions to gain an understanding of circuit operation. Conventional trouble shooting techniques can then be applied. Standard parts are used throughout so that replacement should be of no particular problem.

Use care in replacing diodes and transistors, do not apply excessive heat to the leads. Grip the leads with pliers between the joint and the component.

If necessary, return the instrument to the factory for repair; refer to the warranty.

SECTION X

WARRANTY

F. W. BELL, INC. warrants each instrument of its manufacture to be free from defects in material and workmanship. Our obligation under this warranty is limited to servicing or adjusting any instrument returned to our factory for that purpose, and to replacing any defective parts thereof (excluding electron tubes, batteries, transistors and probe sensing elements, which parts are covered by a standard EIA 90 day warranty). This warranty covers instruments which, within one year after delivery to the original purchaser, shall be returned with transportation charges prepaid by the original purchaser and which upon examination shall disclose to our satisfaction to be defective, if it is determined that the defect has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost after submitting an estimate to the purchaser.

F. W. BELL, INC. reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This warranty is expressly in lieu of all other obligations or liabilities on the part of F. W. BELL, INC., and F. W. BELL, INC. neither assumes nor authorizes any other person to assume for them any other liability in connection with the sales of F. W. BELL, INC. instruments.

DAMAGE IN SHIPMENT

The instrument should be examined and tested as soon as it is received. If it does not operate properly, or is damaged in any way, immediately file a claim with the carrier. The claim agent will provide report forms. A copy of the completed form should be forwarded to us. We will then make the necessary arrangements for repair or replacement. All correspondence concerning this instrument should include model and serial numbers.

SHIPPING INSTRUCTIONS

All shipments of F. W. BELL, INC. instruments should be made via Railway Express or Motor Freight. Always use the original shipping carton and inserts, if possible, or pack the instrument in a sturdy container and surround the entire instrument with two or three inches of excelsior or similar shock-absorbing material.

F. W. BELL, INC.
1356 Norton Avenue
Columbus, Ohio 43212
Phone: 614-294-4906
TWX: 614-759-0193

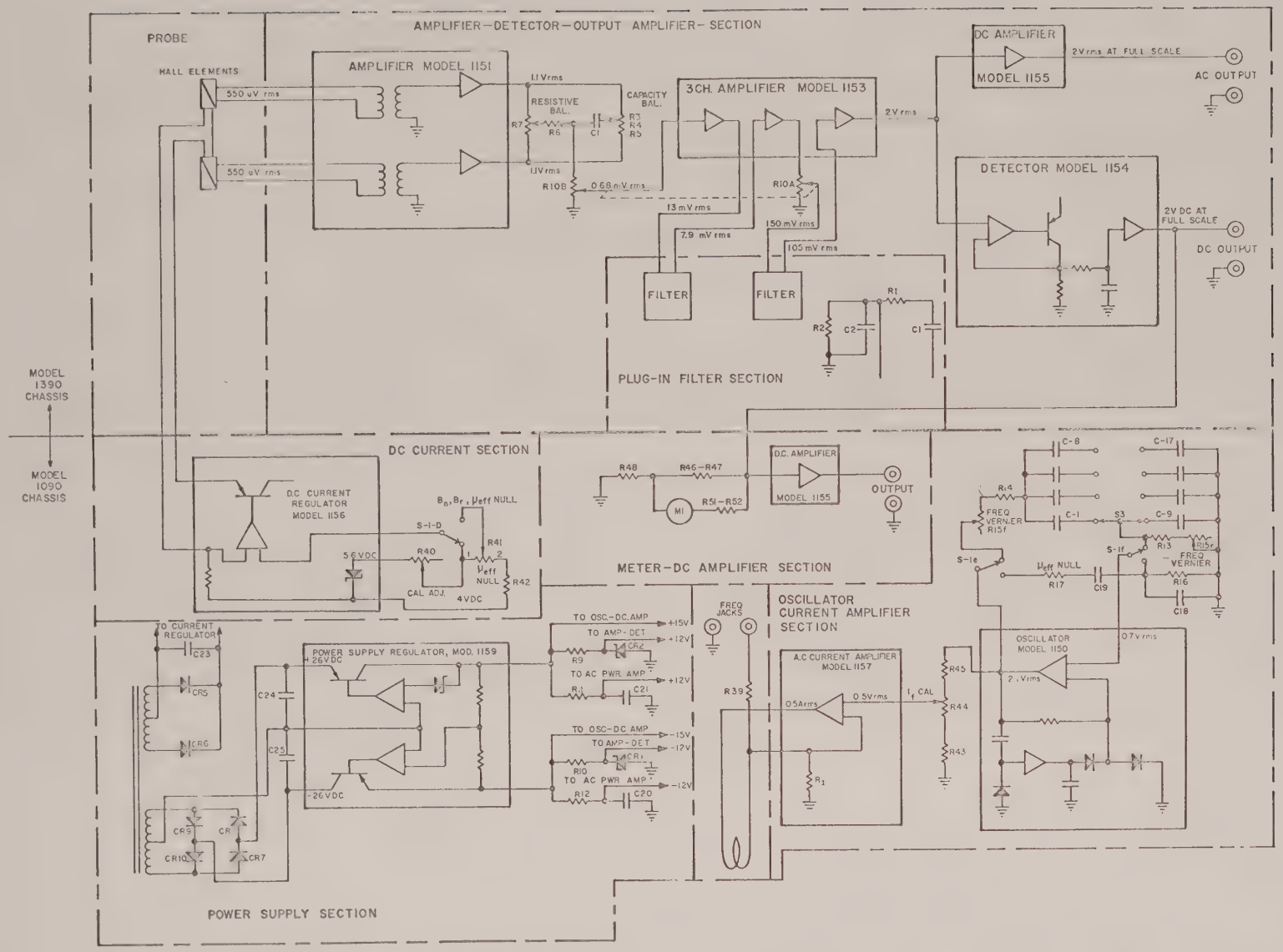


Fig. IV Functional Block Diagram — Model 1390

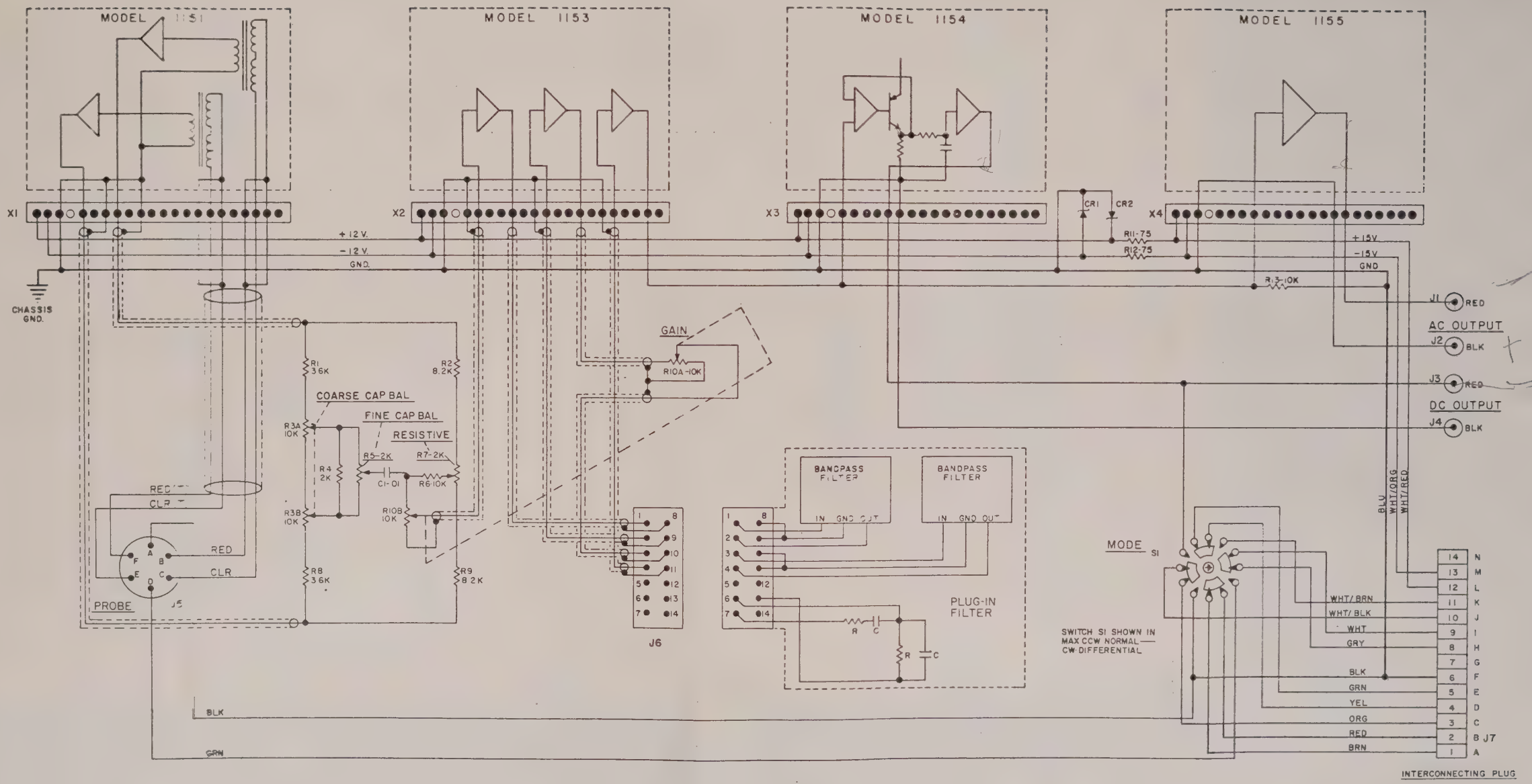


Fig. V Schematic Circuit Diagram — Model 1390

MODEL 1150 OSCILLATOR

GENERAL DESCRIPTION

The Model 1150 is a wide range Wein bridge type oscillator with a well stabilized amplitude regulating circuit. The circuit board does not contain the actual bridge circuit thus being adaptable to fixed frequency as well as variable frequency applications.

SPECIFICATIONS

FREQUENCY RANGE:

20 cps to 100 kcps.

OUTPUT LEVEL:

2.1 volts rms ± 10%

AMPLITUDE STABILITY:

+0.5% 20 cps to 100 kcps.

POWER REQUIREMENTS:

+15 V 3.9 mA and −15 V 10 mA

SIZE:

6½" x 3 9/16" printed circuit module board.

CIRCUIT DESCRIPTION

The output of the external Wein bridge is coupled directly to the base of amplifier Q_1. Q_1 is directly coupled to the complimentary pair Q_2 and Q_3 which also amplify the input. The output of the Q_2, Q_3 pair is directly fed back to the bridge input, to complete the positive frequency selective feedback. Negative feedback for amplitude stability is achieved through the voltage divider action of R_7, R_9, R_{10} and diodes CR_1 to CR_2.

The amplitude stabilizing circuit operates through the variable dynamic impedance characteristics of the diodes CR_1 and CR_2 for different D. C. bias currents.

As the oscillation amplitude builds up a point is reached where the negative peak output voltage swing through C_6 will exceed the negative reference voltage of zener CR_4. C_6 will charge through CR_3 for this peak negative swing. On the positive output voltage swing a point will be reached where Q_4 will be forward biased. At this point Q_4 will conduct, reducing the current through CR_1 and CR_2 and causing them to raise their dynamic impedance. This will increase the negative feedback and limit the oscillation amplitude. The level adjust R_{10} sets the normal range of impedance variation required of the diodes.

Power supply decoupling is supplied through the R_1, R_2 to C_1, C_2 network.

MODEL 1150

Capacitors

					Bell Part No.
C1	200μF	15V	EM	Fixed	CFH-47-200MF
C2	200μF	15V	EM	Fixed	CFH-47-200MF
C3	100μF	6V	EM	Fixed	CFH-11-100MF
C4	25μF	25V	EM	Fixed	CFH-56-25MF
C5	130pF	1KV	CER	Fixed	CRK-03-130pf
C6	100μF	6V	EM	Fixed	CFH-11-100MF
C7	500μF	3V	EM	Fixed	CFH-01-500MF
C8	300μF	3V	EM	Fixed	CFH-01-300MF
C9	100μF	6V	EM	Fixed	CFH-11-100MF
C10	100μF	6V	EM	Fixed	CFH-11-100MF

DIODES

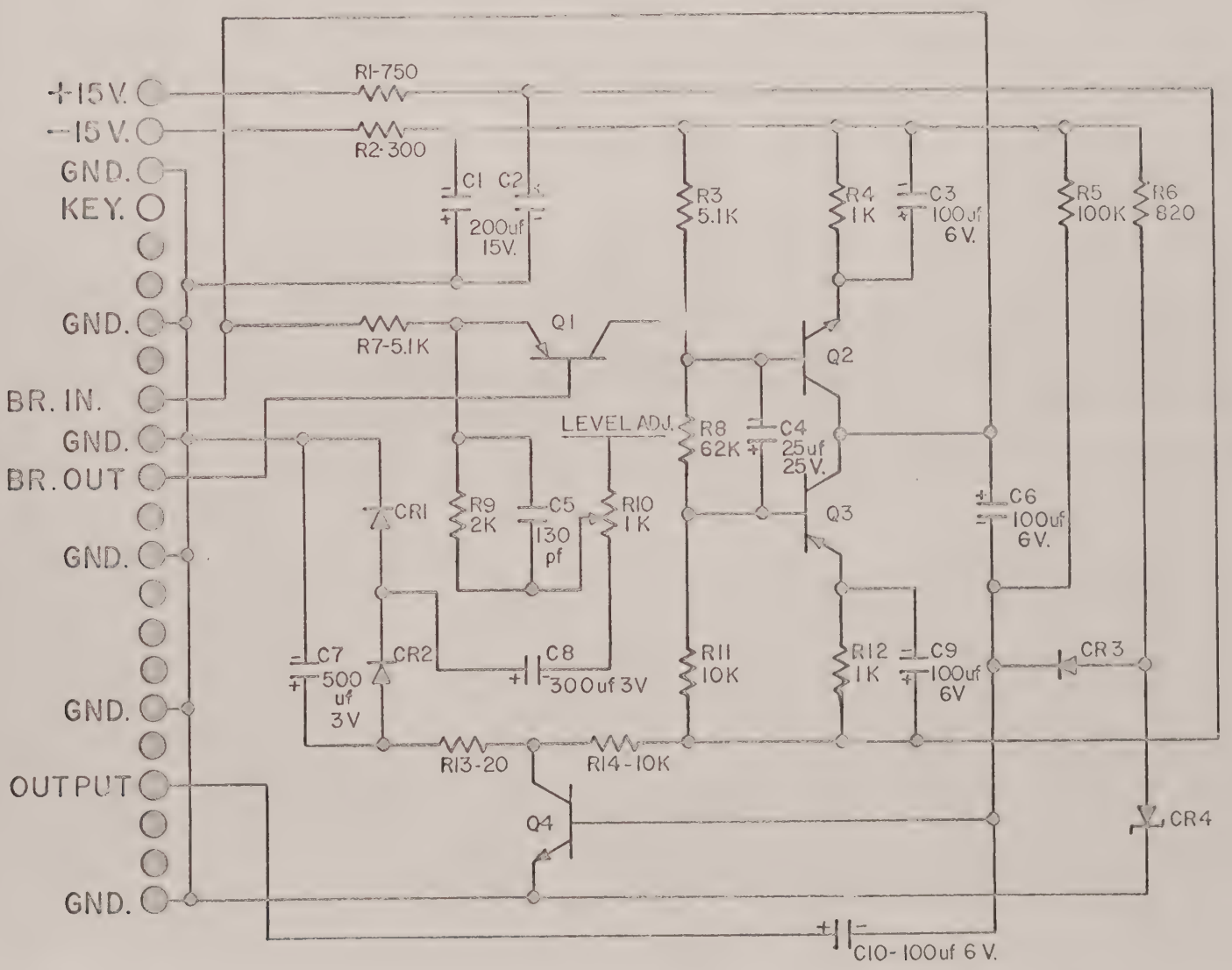
CR1	1N270	JT-1N270
CR2	1N270	JT-1N270
CR3	1N270	JT-1N270
CR4	1N708	JT-1N708

Transistors

Q1	2N1303	JT-2N1303
Q2	2N1302	JT-2N1302
Q3	2N1303	JT-2N1303
Q4	2N1302	JT-2N1302

Resistors

R1	750Ω	½W	5%	Comp	Fixed	RJ-15-750
R2	300Ω	½W	5%	Comp	Fixed	RJ-15-300
R3	5.1kΩ	½W	5%	Comp	Fixed	RJ-15-5X1K
R4	1kΩ	½W	5%	Comp	Fixed	RJ-15-1K
R5	100kΩ	½W	5%	Comp	Fixed	RJ-15-100K
R6	820Ω	½W	5%	Comp	Fixed	RJ-15-820
R7	5.1kΩ	½W	5%	Comp	Fixed	RJ-15-5X1K
R8	62kΩ	½W	5%	Comp	Fixed	RJ-15-62K
R9	2kΩ	½W	5%	Comp	Fixed	RJ-15-2K
R10	1kΩ			WW	VAR.	RS-12-1K
R11	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R12	1kΩ	½W	5%	Comp	Fixed	RJ-15-1K
R13	20Ω	½W	5%	Comp	Fixed	RJ-15-20
R14	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K



Q1 2N1303
Q2 2N1302
Q3 2N1303
Q4 2N1302

CR1 IN 270
CR2 IN 270
CR3 IN 270
CR4 IN 708

SCHEMATIC DIAGRAM MODEL 1150 OSC.

MODEL 1151 DUAL CHANNEL PREAMPLIFIER

GENERAL DESCRIPTION

The Model 1151 Dual Channel Preamplifier contains two identical low level, low noise preamplifiers having a feedback stabilized voltage gain of about 2000 over a band width of 20 Hz to 100 kHz. Both channels are matched as close as possible over the frequency range to provide identical outputs for the same input.

SPECIFICATIONS EACH CHANNEL

VOLTAGE GAIN:
2000

INPUT IMPEDANCE:
50Ω floating from ground

MINIMUM OUTPUT LOAD:
5 kΩ

MAXIMUM INPUT VOLTAGE:
1 mV rms

AVERAGE NOISE REFERRED TO INPUT:
(2Ω source) 0.2 μV approx.

BAND WIDTH:
20 Hz to 100 kHz equalized to ±1%

POWER REQUIREMENTS:
+12 V 10 mA dc and −12 V 10 mA dc

SIZE:
6½" x 3-9/16" printed circuit module card

CIRCUIT DESCRIPTION

This description is for channel 1. Channel 2 is identical except for the resistor, capacitor, and transistor reference numbers.

The input is coupled to Q_1, by the input transformer T_1. Q_1 is direct coupled to Q_2, and dc bias stabilization is achieved by negative feedback through R_5, R_6, and R_7. AC feedback for gain stabilization is applied from the voltage divider off of the output, R_9 and R_4 and through the capacitor C_4 to Q_1's emitter. The preamplifier output is coupled to Q_3 emitter followed through C_3. R_8 is selected for low frequency response equalization and C_5, C_6, and R_{10} are adjusted for high frequency equalization.

The incoming power is decoupled for the preamplifier by R_{21}, R_{22}, C_{13} and C_{14}.

PARTS LIST

Abbreviations:

CER	Ceramic
COMP	Composition
EM	Miniature Electrolytic
FILM	Film Resistor
FOP	Factory adjusted for optimum performance
MME	Miniature Mylar epoxy coated
MPC	Molded Polycarbonate
VAR	Variable
WW	Wire Wound

μ = micro or 10^{-6} k = Kilo or 10^3 p = Pico or 10^{-12}

MODEL 1151

Capacitors

C1	100μF	6V	EM	Fixed	CFH-11-100MF
C2	300μF	3V	EM	Fixed	CFH-01-300MF
C3	4μF	200V	MPC	Fixed	CMR-01-4MF
C4	300μF	3V	EM	Fixed	CFH-01-300MF
C5	FOP	1kV	CER	Fixed	CRK-03-
C6	5-25pF		CER	VAR	CV-03-5-25PF
C7	100μF	6V	EM	Fixed	CFH-11-100MF
C8	300μF	3V	EM	Fixed	CFH-01-300MF
C9	4μF	200V	MPC	Fixed	CMR-01-4MF
C10	300μF	3V	EM	Fixed	CFH-01-300MF
C11	FOP	1kV	CER	Fixed	CRK-03-
C12	5-25pF		CER	VAR	CV-03-5-25PF
C13	200μF	12V	EM	Fixed	CFH-32-200MF
C14	200μF	12V	EM	Fixed	CFH-32-200MF

Transistors

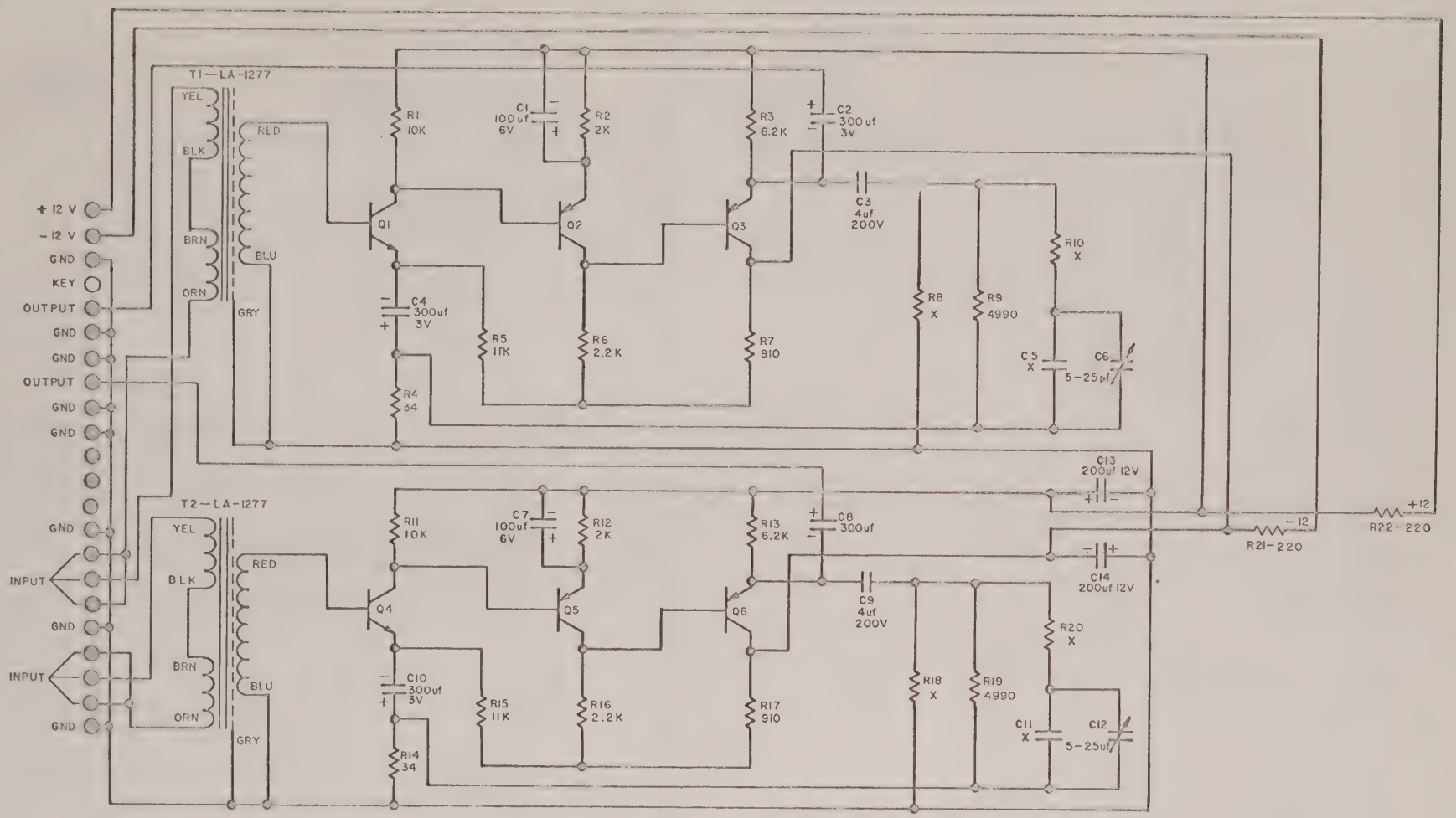
Q1	2N3707	JT-2N3707
Q2	2N2614	JT-2N2614
Q3	2N2614	JT-2N2614
Q4	2N3707	JT-2N3707
Q5	2N2614	JT-2N2614
Q6	2N2614	JT-2N2614

Transformers

T1	Input	LA-1277
T2	Input	LA-1277

Resistors

R1	10kΩ	½W	1%	Film	Fixed	RK-14-10K
R2	2kΩ	½W	5%	Comp	Fixed	RJ-15-2K
R3	6.2kΩ	½W	5%	Comp	Fixed	RJ-15-6X2K
R4	34Ω	1W	1%	W.W.	Fixed	RL-03-34
R5	11kΩ	½W	5%	Comp	Fixed	RJ-15-11K
R6	2.2kΩ	½W	5%	Comp	Fixed	RJ-15-2X2K
R7	910Ω	½W	5%	Comp	Fixed	RJ-15-910
R8	FOP	½W	5%	Comp	Fixed	RJ-15-
R9	4.99kΩ	½W	1%	Film	Fixed	RK-14-4X99K
R10	FOP	½W	5%	Comp	Fixed	RJ-15-
R11	10kΩ	½W	1%	Film	Fixed	RK-14-10K
R12	2kΩ	½W	5%	Comp	Fixed	RJ-15-2K
R13	6.2kΩ	½W	5%	Comp	Fixed	RJ-15-6X2K
R14	34Ω	1W	1%	W.W.	Fixed	RL-03-34
R15	11kΩ	½W	5%	Comp	Fixed	RJ-15-11K
R16	2.2kΩ	½W	5%	Comp	Fixed	RJ-15-2X2K
R17	910Ω	½W	5%	Comp	Fixed	RJ-15-910
R18	FOP	½W	5%	Comp	Fixed	RJ-15-
R19	4.99kΩ	½W	1%	Film	Fixed	RK-14-4X99K
R20	FOP	½W	5%	Comp	Fixed	RJ-15-
R21	220Ω	½W	5%	Comp	Fixed	RJ-15-220
R22	220Ω	½W	5%	Comp	Fixed	RJ-15-220



Q1 & Q4 — 2N3707
Q2 & Q3 — 2N2614
Q5 & Q6 — 2N2614

SCHEMATIC DIAGRAM MODEL 1151 DUAL CHANNEL PREAMPLIFIER

MODEL 1153

THREE CHANNEL AMPLIFIER

GENERAL DESCRIPTION

The Model 1153 three-channel amplifier contains 3 identical medium level amplifiers having feedback stabilized voltage gains of about 19 over a band width of 20 Hz to 100 kHz each. All have identical responses making them useful for multi-channel instrument systems requiring matched characteristics.

SPECIFICATIONS EACH CHANNEL

VOLTAGE GAIN:
approx. 19

INPUT IMPEDANCE:
10 kΩ

MINIMUM OUTPUT LOAD:
5 kΩ

MAXIMUM INPUT VOLTAGE:
0.11 V ac rms

BAND WIDTH:
20 Hz to 100 kHz ±1% response

POWER REQUIREMENTS:
+ 12 V 10 mA dc and —12 V 10 mA dc

SIZE:
6½" x 3-9/16" printed circuit module card

CIRCUIT DESCRIPTION

This description is for channel 1. Channels 2 and 3 are identical except for resistor, capacitor and transistor reference numbers.

The input is direct coupled to the base of Q_1 with R_1 shunting to ground to give the input impedance of 10 kΩ. Q_1 is direct coupled to Q_2, and dc bias stabilization is achieved by dc feedback to Q_1's emitter through R_8, R_9, and R_{10}. AC gain stabilizing feedback is taken from the divider off of the output, R_6 and R_7 through C_3 to Q_1's emitter.

The power is decoupled for each channel individually. R_3, R_{11}, C_2 and C_5 for channel 1; R_{16}, R_{23}, C_7 and C_{10} for channel 2; and R_{26}, R_{33}, C_{12} and C_{15} for channel 3.

PARTS LIST

Abbreviations:

Comp — Composition
EM — Miniature Electrolytic
μ = Micro or 10^{-6} k = Kilo or 10^3

MODEL 1153

Capacitors

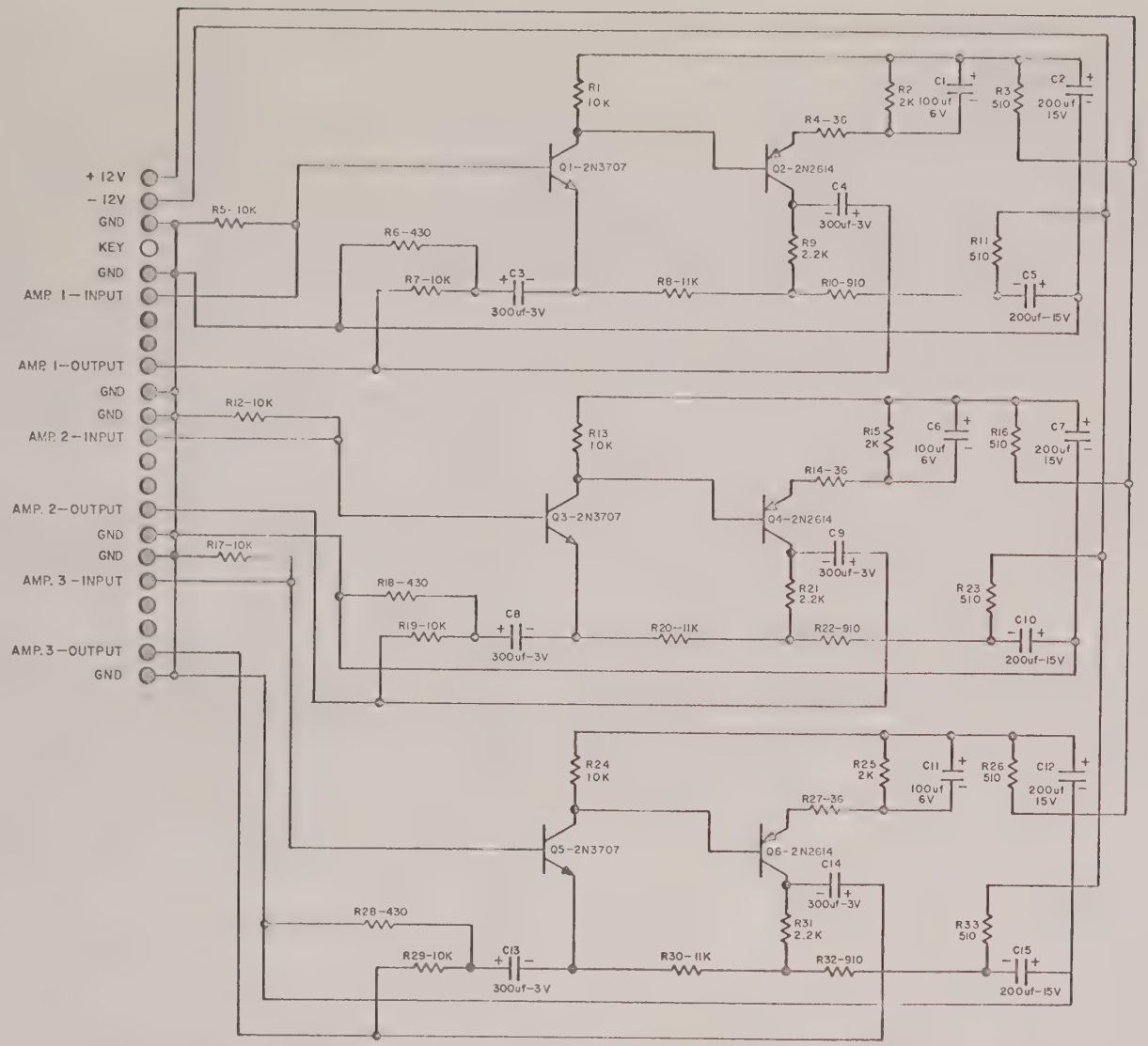
C1	100μF	6V	EM	Fixed	CFH-11-100MF
C2	200μF	15V	EM	Fixed	CFH-47-200MF
C3	300μF	3V	EM	Fixed	CFH-01-300MF
C4	300μF	3V	EM	Fixed	CFH-01-300MF
C5	200μF	15V	EM	Fixed	CFH-47-200MF
C6	100μF	6V	EM	Fixed	CFH-11-100MF
C7	200μF	15V	EM	Fixed	CFH-47-200MF
C8	300μF	3V	EM	Fixed	CFH-01-300MF
C9	300μF	3V	EM	Fixed	CFH-01-300MF
C10	200μF	15V	EM	Fixed	CFH-47-200MF
C11	100μF	6V	EM	Fixed	CFH-11-100MF
C12	200μF	15V	EM	Fixed	CFH-47-200MF
C13	300μF	3V	EM	Fixed	CFH-01-300MF
C14	300μF	3V	EM	Fixed	CFH-01-300MF
C15	200μF	15V	EM	Fixed	CFH-47-200MF

Transistors

Q1	2N3707	JT-2N3707
Q2	2N2614	JT-2N2614
Q3	2N3707	JT-2N3707
Q4	2N2614	JT-2N2614
Q5	2N3707	JT-2N3707
Q6	2N2614	JT-2N2614

Resistors

R1	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R2	2kΩ	½W	5%	Comp	Fixed	RJ-15-2K
R3	510Ω	½W	5%	Comp	Fixed	RJ-15-510
R4	36Ω	½W	5%	Comp	Fixed	RJ-15-36
R5	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R6	430Ω	½W	5%	Comp	Fixed	RJ-15-430
R7	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R8	11kΩ	½W	5%	Comp	Fixed	RJ-15-11K
R9	2.2kΩ	½W	5%	Comp	Fixed	RJ-15-2X2K
R10	910Ω	½W	5%	Comp	Fixed	RJ-15-910
R11	510Ω	½W	5%	Comp	Fixed	RJ-15-510
R12	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R13	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R14	36Ω	½W	5%	Comp	Fixed	RJ-15-36
R15	2kΩ	½W	5%	Comp	Fixed	RJ-15-2K
R16	510Ω	½W	5%	Comp	Fixed	RJ-15-510
R17	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R18	430Ω	½W	5%	Comp	Fixed	RJ-15-430
R19	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R20	11kΩ	½W	5%	Comp	Fixed	RJ-15-11K
R21	2.2kΩ	½W	5%	Comp	Fixed	RJ-15-2X2K
R22	910Ω	½W	5%	Comp	Fixed	RJ-15-910
R23	510Ω	½W	5%	Comp	Fixed	RJ-15-510
R24	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R25	2kΩ	½W	5%	Comp	Fixed	RJ-15-2K
R26	510Ω	½W	5%	Comp	Fixed	RJ-15-510
R27	36Ω	½W	5%	Comp	Fixed	RJ-15-36
R28	430Ω	½W	5%	Comp	Fixed	RJ-15-430
R29	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R30	11kΩ	½W	5%	Comp	Fixed	RJ-15-11K
R31	2.2kΩ	½W	5%	Comp	Fixed	RJ-15-2X2K
R32	910Ω	½W	5%	Comp	Fixed	RJ-15-910
R33	510Ω	½W	5%	Comp	Fixed	RJ-15-510



SCHEMATIC DIAGRAM MODEL 1153 THREE CHANNEL AMPLIFIER

MODEL 1154 DETECTOR

GENERAL DESCRIPTION

The Model 1154 is a high linearity A. C. to D. C. convector or detector having very low output impedance to drive meters, chart recorders, etc. It is an average type detector circuit; having a filtered output for low ripple.

SPECIFICATIONS

MAXIMUM INPUT LEVEL:

2 volts rms

CONVERSION EFFICIENCY:

$\frac{\text{E. D. C. out}}{\text{E rms. in}} = 1 \pm 10\%$

for sinusoidal wave forms.

LINEARITY:

$\pm 0.25\%$ of full scale, 2 volts, from 10% of full scale to full scale.

FREQUENCY RESPONSE:

$< \pm$ 0.5%, 20 Hz to 100 kHz

OUTPUT IMPEDANCE:

$< 10\ \Omega$

OUTPUT RIPPLE AT 20 cps:

< 10%

POWER REQUIREMENTS:

+12 V — 12 mA and — 12V — 12 mA

SIZE:

6½" x 3 9/16" printed circuit module card.

CIRCUIT DESCRIPTION

The input is direct coupled to the impedance transformer emitter follower Q_8. It then goes to the difference amplifier comprising Q_1, Q_4 and Q_5. This high gain amplifier is unique in that R_{19}, the collector load resistor for Q_1, is grounded, thus capable of output only on positive half cycles. On negative half cycles, Q_1 remains cut off, preventing output. Emitter follower Q_3, couples the difference amplifier output and feeds the negative feedback voltage divider, R_{13} and R_{18}. On positive half cycles, then, the output is of the same wave shape as the input and of such a magnitude that the D. C. average voltage is equal to the A. C. rms. input. On negative half cycles no output is obtained. The break point as the input passes through zero volts is made very sharp by the high loop gain of the difference amplifier and hence high linearity A. C. to D. C. conversion is possible.

The D. C. output is filtered by R_{14} and C_6, and feeds to the unity gain D. C. output amplifier comprised of Q_6, Q_7 and Q_2. Thus, low output impedance is possible to handle meters, recorders, etc.

PARTS LIST

Abbreviations:

CER	Ceramic
COMP	Composition
EM	Miniature Electrolytic
MME	Miniature Epoxy Molded
VAR	Variable
WW	Wirewound

μ = Micro or 10^{-6}
p = Pico or 10^{-12}
k = Kilo or 10^3

MODEL 1154

Capacitors

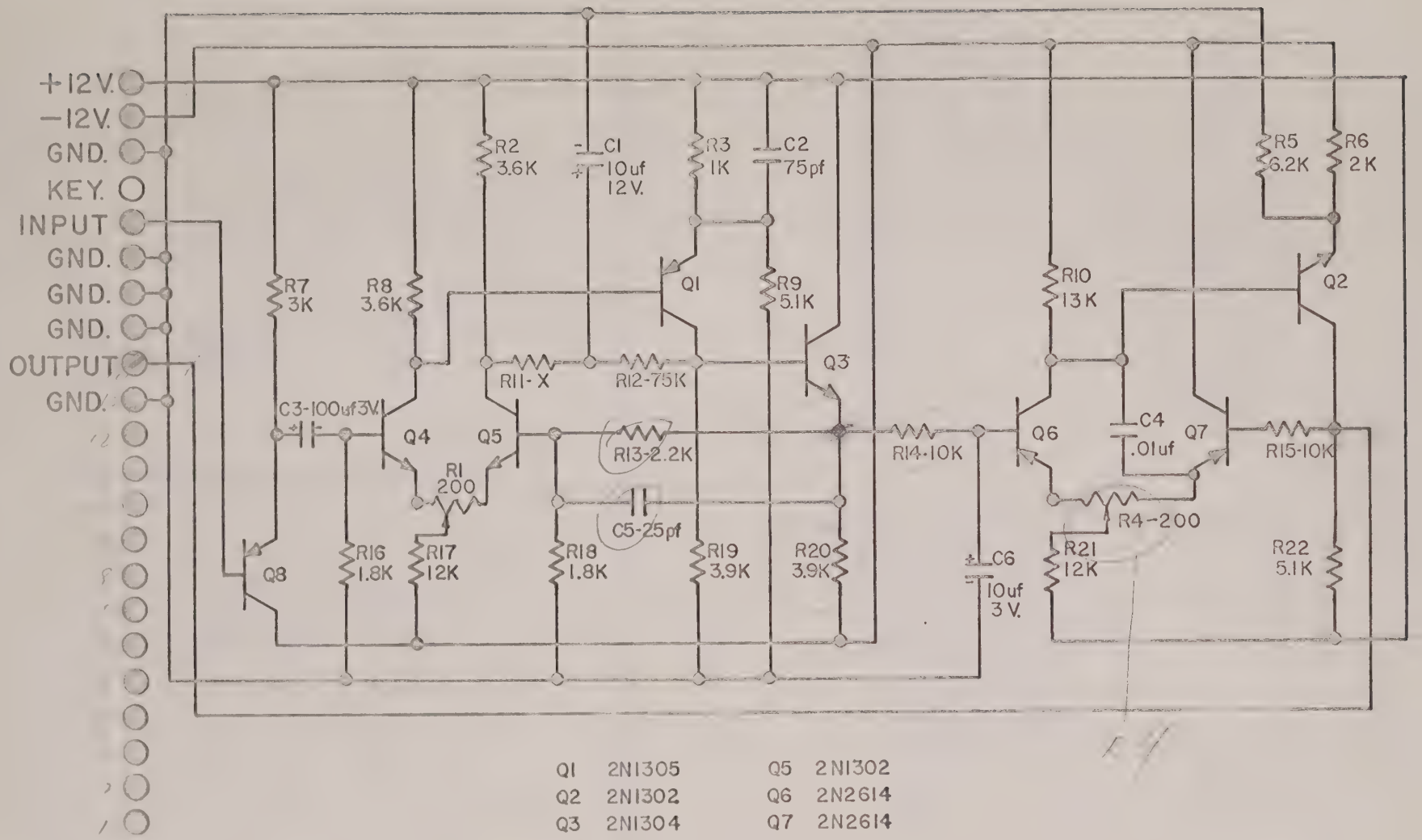
					Bell Part No.
C1	10μF	12V	EM	Fixed	CFH-32-10MF
C2	75pF	1kV	CER	Fixed	CRK-03-75pf
C3	100μF	3V	EM	Fixed	CFH-01-100MF
C4	.01μF	200V	MME	Fixed	CLP-11-X01MF
C5	25pF	1kV	CER	Fixed	CRK-03-25pf
C6	10μF	3V	EM	Fixed	CFH-01-10MF

Transistors

Q1	2N1305	JT-2N1305
Q2	2N1302	JT-2N1302
Q3	2N1304	JT-2N1304
Q4	2N1302	JT-2N1302
Q5	2N1302	JT-2N1302
Q6	2N1374	JT-2N1374
Q7	2N1374	JT-2N1374
Q8	2N1303	JT-2N1303

Resistors

R1	200Ω			WW	VAR.	RS-12-200
R2	3.6kΩ	½W	5%	Comp	Fixed	RJ-15-3X6K
R3	1kΩ	½W	5%	Comp	Fixed	RJ-15-1K
R4	200Ω			WW	VAR.	RS-12-200
R5	6.2kΩ	½W	5%	Comp	Fixed	RJ-15-6X2K
R6	2kΩ	½W	5%	Comp	Fixed	RJ-15-2K
R7	3kΩ	½W	5%	Comp	Fixed	RJ-15-3K
R8	3.6kΩ	½W	5%	Comp	Fixed	RJ-15-3X6K
R9	5.1kΩ	½W	5%	Comp	Fixed	RJ-15-5X1K
R10	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R11	FOP	½W	5%	Comp	Fixed	RJ-15-
R12	75kΩ	½W	5%	Comp	Fixed	RJ-15-75K
R13	2.2kΩ	½W	5%	Comp	Fixed	RJ-15-2X2K
R14	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R15	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R16	1.8kΩ	½W	5%	Comp	Fixed	RJ-15-1X8K
R17	12kΩ	½W	5%	Comp	Fixed	RJ-15-12K
R18	1.8kΩ	½W	5%	Comp	Fixed	RJ-15-1X8K
R19	3.9kΩ	½W	5%	Comp	Fixed	RJ-15-3X9K
R20	3.9kΩ	½W	5%	Comp	Fixed	RJ-15-3X9K
R21	12kΩ	½W	5%	Comp	Fixed	RJ-15-12K
R22	5.1kΩ	½W	5%	Comp	Fixed	RJ-15-5X1K



Q1	2N1305	Q5	2N1302
Q2	2N1302	Q6	2N2614
Q3	2N1304	Q7	2N2614
Q4	2N1302	Q8	2N1303

SCHEMATIC DIAGRAM MODEL 1154 DETECTOR

MODEL 1155 D.C. AMPLIFIER

GENERAL DESCRIPTION

The Model 1155 is a unity gain amplifier providing high input impedance and very low output impedance. The amplifier will operate over the range of D. C. to 10 kcps with resistive, capacitive or inductive loads with up to 3 volts D. C. or rms at 15 mA output.

SPECIFICATIONS

GAIN:

Unity

INPUT IMPEDANCE:

$> 100\,k\Omega$

OUTPUT IMPEDANCE:

$< 0.1\ \Omega$

FREQUENCY RESPONSE:

D. C. to 10 kcps $< \pm 0.1$ dB

MAXIMUM OUTPUT:

3 volts D. C. or rms up to 15 mA (output peak clips at higher currents thus protecting against overloading)

POWER REQUIREMENTS:

+15 V 18 mA max. and −15 V 18 mA max.

SIZE:

6½" x 3 9/16" printed circuit module card.

CIRCUIT DESCRIPTION

Q_1 and Q_2 form a difference amplifier with the input being fed to Q_1 and the feedback being fed to Q_2. Q_3 is a voltage amplifier direct coupled to Q_1 and feeds the dual emitter follower Q_4 and Q_5. CR_1 provides a small amount of forward bias for the dual emitter followers. R_4 provides for zero adjustment and C_1, C_2, and C_3 shape the open loop response to stabilize the amplifier under the conditions of various reactive loads. R_3 and R_9 are inserted to prevent excessive output currents from being drawn in the case of a short circuit of the output. They will cause peak clipping in the case of A. C. signals and limit D. C. signals to safe output current levels.

MODEL 1155

Capacitors

					Bell Part No.
C1	220pF	1kV	CER	Fixed	CRK-03-220pf
C2	220pF	1kV	CER	Fixed	CRK-03-220pf
C3	.0022μF	200V	MME	Fixed	CRLP-11-X0022MF

DIODE

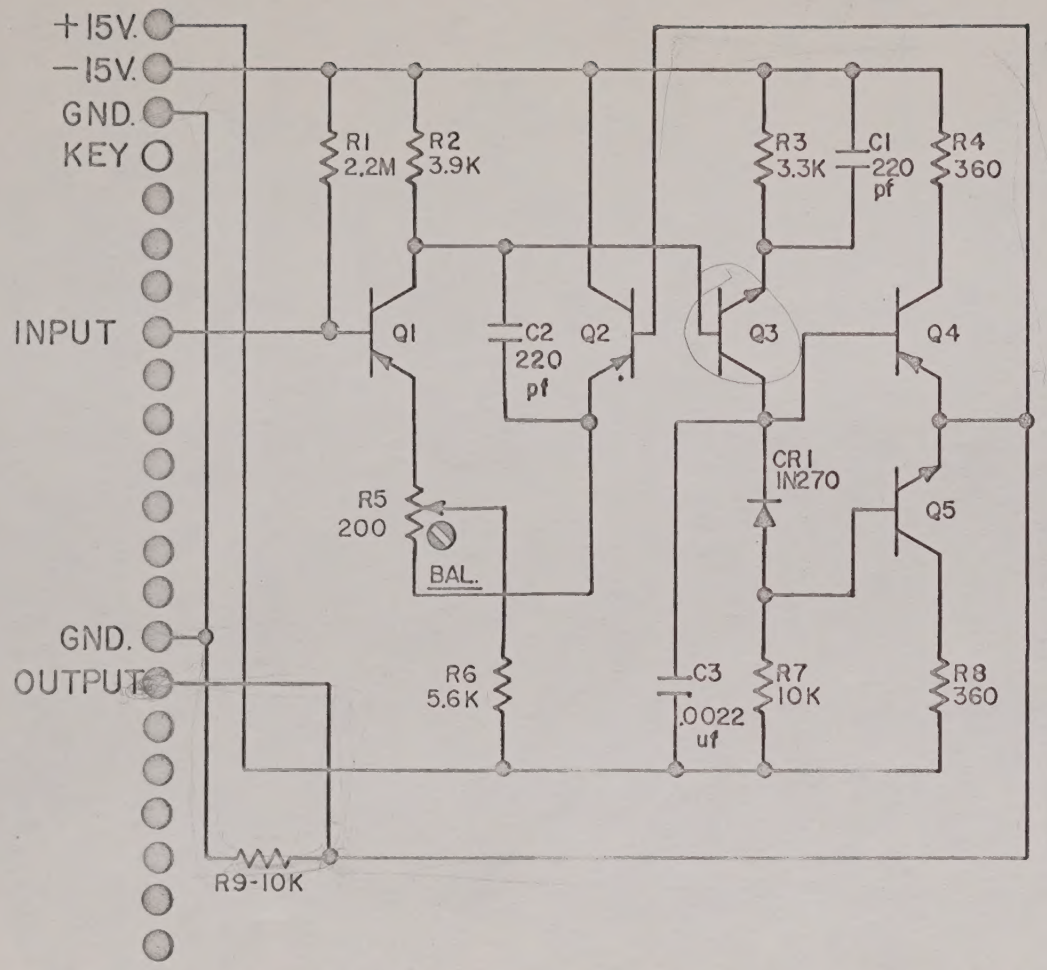
CR1	1N270	JT-1N270

Transistors

Q1	2N2614	JT-2N2614
Q2	2N2614	JT-2N2614
Q3	2N1302	JT-2N1302
Q4	2N1303	JT-2N1303
Q5	2N1302	JT-2N1302

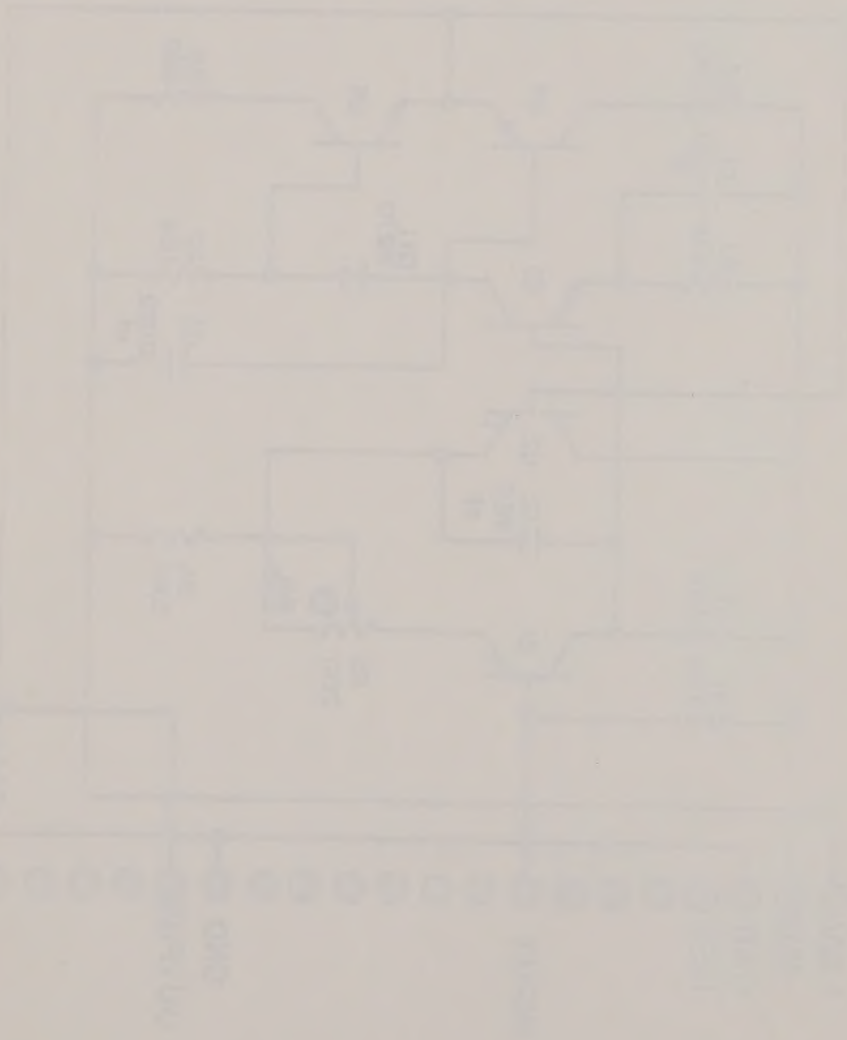
Resistors

R1	2.2MΩ	½W	5%	Comp	Fixed	RJ-15-2X2M
R2	3.9kΩ	½W	5%	Comp	Fixed	RJ-15-3X9K
R3	3.3kΩ	½W	5%	Comp	Fixed	RJ-15-3X3K
R4	360Ω	½W	5%	Comp	Fixed	RJ-15-360
R5	200Ω			WW	VAR.	RS-11-200
R6	5.6kΩ	½W	5%	Comp	Fixed	RJ-15-5X6K
R7	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K
R8	360Ω	½W	5%	Comp	Fixed	RJ-15-360
R9	10kΩ	½W	5%	Comp	Fixed	RJ-15-10K



Q1 2N2614
Q2 2N2614
Q3 2N1302
Q4 2N1303
Q5 2N1302

SCHEMATIC DIAGRAM MODEL 1155 DC AMP.



MISSILE & SPACE SYSTEMS DIVISION
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